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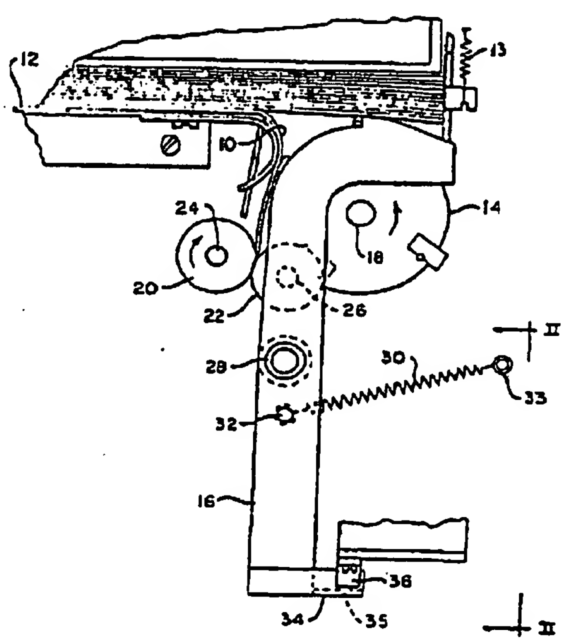
(54) Title: APPARATUS FOR DETECTING THE PASSAGE OF MULTIPLE DOCUMENTS

(57) Abstract

An apparatus for detecting the passage of multiple documents (10) in a transport system, including a pair of rollers (20, 22) between which said documents (10) are arranged to pass and which are displaceable by an extend dependent on the thickness of one document or multiple documents simultaneously passing therebetween. This displacement is measured by the movement of a graded density translucent member (34) between the photodiode (46) and sensor (40) of a detector (36). Electronic circuitry associat d with the detector (36) indicates the presence of a record member (10) between the rollers (20, 22), and also the presence of multiple record members (10). The graded density of the member (34) allows the circuitry to detect only the displacement from the static position of the rollers (20, 22) eliminating the necessity for adjustment due to wear, temperature, and other mechanical factors.



or a combination thereof, to sense the presence of multiple bills. Overall performance of a doubles detector, however, depends heavily on the means of determining if a document has been fed, and if so, whether it was a single document.

A double document detector is described in the IBM Technical Disclosure Bulletin, Vol. 7, No. 8 of January 1965, in which the documents are arranged to pass between a pair of cooperating rollers. One of the rollers has an arm attached thereto and is displaceable relative to the other by an extent dependent on the thickness of the documents passing between the rollers. If a single document passes between the rollers, the arm is moved from the home position to a position in which it will not prevent light from passing through an aperture to impinge upon a light sensitive element. When overlapped documents pass between the rollers, the arm is moved to a position to cover the aperture and prevent light from reaching the element, thereby indicating an overlapped document condition.

A disadvantage of this arrangement is that static changes in the position of the rollers, caused by wear, elasticity or accumulation of foreign matter, may result in a drift of the operating range of the system causing erroneous operation.

Disclosure of the Invention

It is an object of the present invention to provide an efficient multiple document detector with a simple, low cost, design in which the above disadvantage is alleviated.

Thus, according to the invention, there is provided an apparatus for detecting the passage of multiple documents in a transport system, including a gauging means through which documents are arranged to pass, said gauging means being displaceable by an extent dependent on the thickness of one document or multiple

documents passing therethrough, characterized by detecting means which is coupled to said gauging means and which is arranged to produce an output which progressively varies in response to a displacement of said gauging means, and circuit means, responsive to said detecting means, for producing an indication of whether multiple documents have simultaneously passed through said gauging means.

Brief Description of the Drawings

One embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is a diagrammatic view illustrating certain components of a currency dispenser;

Fig. 2 shows a partial sectional view of the currency dispenser taken along the line 2-2 of Fig. 1;

Fig. 3 is a schematic diagram of the monitoring circuitry of the currency dispenser;

Fig. 4 shows the unfiltered waveform of a single bill passing through the currency dispenser with its leading edge folded over;

Fig. 5 shows the unfiltered waveform of a double bill passing through the currency dispenser;

Fig. 6 shows the waveforms of several bills as inputs to the doubles detection comparator;

Fig. 7 shows the waveforms of several bills as inputs to the presence detection comparator;

Fig. 8 is a graph of the output voltages of several detectors versus displacement of the film strip;

Fig. 9 is a graph of the normalized output voltage of several detectors versus displacement of the film strip from the energized center position.

Best Mode of Carrying Out the Invention

Referring now to Fig. 1, there are shown certain components of a currency dispenser. Currency bills

or other documents 10 are urged against a table 12 by spring 13 for feeding. A pair of spaced-apart driving wheels 14, each located between two adjacent arms of an assembly 16, are fixed to a shaft 18 to be driven thereby. During the feeding operation, currency 10 is urged by driving wheels 14 between a pair of rollers 20 and 22. Preferably, both rollers are composed of an aluminum core with a polyurethane covering. Feed roller 20 is fixed at the end of a motor shaft 24, which rotates at a surface speed of 250 centimeters per second. Idler roller 22 is rotatably mounted on a short shaft 26, which freely rotates in the arms of assembly 16. Arm assembly 16 is pivotally mounted on a shaft 28 and tensioned by a spring 30, which spring is attached to arm assembly 16 at connecting pin 32. The opposite end of spring 30 is attached to a short shaft 33. Spring 30 applies a force on arm assembly 16 such that roller 22 is urged into cooperating engagement with roller 20. For a more detailed description of the above-described structure, reference is made to the previously-mentioned U.S. Patent No. 4,168,058.

As currency 10 is fed between rollers 20 and 22, roller 22 is forced away from roller 20 a distance equal to the thickness of the currency 10, causing arm assembly 16 to pivot about shaft 28, and displacing the bottom of arm assembly 16 in the direction toward roller 20. In the present embodiment, the distance between shaft 28 and the bottom of arm assembly 16 is three times greater than the distance between shaft 28 and shaft 26; therefore, the bottom of arm assembly 16 is displaced toward roller 20 three times further than roller 22 is moved away from roller 20 when currency 10 is fed between rollers 20 and 22. Consequently, when using U.S. currency, which has a normal average thickness of 0.010 centimeters, the bottom end of arm assembly 16 will travel approximately 0.030 centimeters when a single bill passes between rollers 20 and 22.

A processed photographic film strip 34 is bonded along a protrusion 35 on the end of arm assembly 16. Film strip 34 is attached to arm assembly 16 such that it moves between the light source and sensor of a detector module 36 as the bottom end of arm assembly 16 is displaced. Since film strip 34 is processed in such a manner as to exhibit a relatively rapid change in optical density in a direction parallel to its length, the described motion of arm assembly 16 will change the amount of light activating the sensor of module 36. Thus, the electrical output of detector 36 is relative to the position of arm assembly 16.

In the present embodiment, the currency dispenser monitor is used to detect the presence of a single bill in addition to sensing the presence of multiple bills. However, due to several different factors, the home position of rollers 20 and 22 may change. Causes for the position drift may be variations in the resilience of the polyurethane surface covering of the rollers, wearing of the surfaces, ink deposits from the bills, wear in the bearings, or changes in ambient temperatures which cause expansion or contraction of the machine base and components. Experimental analysis of this home position drift indicates that it may shift plus or minus 0.075 centimeters from its initial position. Therefore, assuming a 0.075 centimeter displacement being necessary for detecting multiple bills, a linear measurement range of 0.225 centimeters is preferred for satisfactory operation of the doubles detector.

In the preferred embodiment, for cost considerations it is desirable to use a low-cost and commercially-available component in the circuit of detector 36 which is pre-aligned, and has a sufficiently high electrical output to provide direct drive of the associated electronic circuitry. A satisfactory component is General Electric type H13B1 photon-coupled interruptor

module, which is composed of a gallium arsenide solid-state lamp illuminating a silicon photo-darlington sensor across an air gap of 0.318 centimeters. This component and the film strip provide the entire optical system for the present currency dispenser monitor.

These detector units, however, have an active optical area of only 0.050 to 0.075 centimeters. Therefore, if the film strip contained a sharp opaque/transparent transition line, the desired range of 0.225 centimeters could not be reached. To expand the operating range, an incrementally graded density film strip is used.

A method and apparatus for producing such a film strip is disclosed in an international application filed by the present Applicants on the same day as the present application entitled "Method and Apparatus for Fabricating a Translucent Graded Density Medium" (NCR Docket No. 2905).

The film strip having a substantially linear density gradient enables the detector to operate over a greater travel distance. Any movement of the film will cause a change in the intensity of light which the sensor of the detector receives; therefore, the length of the filmstrip determines the operating range of the detector.

Fig. 3 shows the electronic circuitry which, taken together with detector 36, comprises the monitor control. A phototransistor 40 contained within detector 36 acts as a variable resistor between the supply voltage 42, which is filtered by capacitors 43 and 44, and line 45. The resistance of phototransistor 40 is controlled by illumination emitted by a photodiode 46 also contained within detector 36. As the illumination from photodiode 46 increases when film strip 34 is moved in one direction within the air gap between the components of detector 36, the circuit voltage becomes more positive across a resistor 47 with r spect to ground 48. The voltage on

line 45 is also applied to a filtering combination of resistor 49 and capacitor 50. The coupling capacitor 50 blocks the DC component of the voltage at 45, which voltage is proportional to the quiescent position of film strip 34, arm assembly 16, and roller 22, allowing the circuit to respond only to changes in the position of film strip 34 between the components of detector 36. Thus, the circuit of Fig. 3 is independent of the static position of rollers 20 and 22, and reacts only to a physical movement of roller 22, which also causes movement of arm assembly 16 and film strip 34; mechanical drift of the static roller position will not affect the proper operation of the circuit.

Current to operate photodiode 46 is supplied from a voltage regulator 51 via a potentiometer 52. Regulator 51 may be an integrated circuit chip, such as Motorola Type MC1723CL or its equivalent, and serves to insure a sufficient calibrated current supply to photodiode 46 for proper operation. Regulator 51 and its associated components (resistors 54, 56, 58 and capacitor 60) may be eliminated if the power supply used to drive the circuit is sufficiently stable.

The output 61 of regulator 51, which is approximately 8 volts, is applied to another portion of the detection circuitry via resistors 62 and 64 and a diode 66. Diode 66 tends to hold the voltage across resistor 64 on the cathode of capacitor 50, which provides a fast recovery from the charge condition on capacitor 50.

The voltage at 68 is applied to the non-inverting input 69 of a differential comparator 70 via an integrating network of resistor 72 and capacitor 74. Comparator 70, which may be a Motorola type MC1414L or its equivalent, detects the presence of more than one bill between rollers 20 and 22. The reference voltage for the inverting input 75 of comparator 70 is generated when the supply voltag at 42 is transmitted across a

series combination of a resistor 78 and a zener diode 80. The voltage present across zener diode 80, which is approximately 3.9 VDC, is transmitted to the strobe input 81 of comparator 70, and also to input 75 via a resistor 82 and a potentiometer 84. Potentiometer 84 makes it possible to adjust the reference voltage for input 75 to a desired level for precise detection of a single bill thickness. Thus, when the voltage at input 69 exceeds the reference voltage at 75 by a few millivolts, indicating that a doubles condition has occurred, comparator 70 outputs a fast rising TTL compatible signal at terminal 86 across a load resistor 88.

Detection of the presence of a single bill is accomplished in a similar manner. The voltage at 68 is applied to the non-inverting input 90 of a differential comparator 92 via an integrating network of a resistor 94 and a capacitor 96. Comparator 92 may be a Motorola type MC1414L or its equivalent. The reference voltage across zener diode 80 is applied to the strobe input 97 of comparator 92, and also to the inverting input 98 via a resistor 100 and a potentiometer 102. Potentiometer 102 adjusts the reference voltage for input 98 to a desired level such that the signal received at input 90 exceeding this reference voltage is indicative of one or more bills passing between rollers 20 and 22. Thus, when the voltage at input 90 exceeds the reference voltage at 98 by a few millivolts, comparator 92 outputs a signal to terminal 104 across a load resistor 106, indicating the presence of at least a single bill between rollers 20 and 22.

The necessity for the integrating network of resistor 72/capacitor 74 is illustrated by the waveforms shown in Figs. 4 and 5. Fig. 4 shows the waveform of the voltage at 68 when a single bill with the leading edge folded back approximately one-half inch is inserted between rollers 20 and 22. The initial bounce caused as the bill enters rollers 20 and 22 is of sufficient

amplitude to trigger comparator 70, which would output a false double detection signal. As a comparison, Fig. 5 shows the waveform of the voltage at 68 when a double bill travels between rollers 20 and 22. The signal in Fig. 5 shows the initial bounce caused by the double bill entering rollers 20 and 22, but the signal also remains at a sufficient level for triggering comparator 70 for a longer time period, due to the extra thickness along the entire length of the bill. When the integrating network is used, the initial bounce is softened, allowing comparator 70 to detect only true double bills.

Fig. 6 shows waveforms of the signals generated by various bills at input 69 to comparator 70, which signals have been smoothed by the integrating network of resistor 72/ capacitor 74. Line 110 represents the double detection threshold; any signal rising above this will trigger comparator 70.

Signal 112 represents a double bill with its leading edge folded back approximately one-half inch; it is readily detected by comparator 70. Signal 114 shows a double bill; it is also detected by comparator 70. Signal 116 represents a single bill with its leading edge folded back approximately one-half inch; the integrating network has filtered the signal so that it will not cause comparator 70 to falsely trigger. Signal 118 shows the waveform for an unfolded single bill; it also is not great enough to activate comparator 70. Finally, the idle noise of the circuitry is represented by signal 120.

A lesser degree of integration is provided by the integrating network of resistor 94/capacitor 96, which balances the signal to eliminate noise pulses from mechanical shock, and yet preserve the pulse width as a means of detecting the time of bill entry and removal from rollers 20 and 22. Fig. 7 shows waveforms of the signals generated by various bills at input 90 to comparator 92, which signals have been smoothed by the

integrating network of resistor 94/capacitor 96. Line 121 indicates the present detect threshold; any signal rising above this will trigger comparator 92.

Signal 122 represents a double bill, signal 124 represents a single bill with the leading edge folded back one-half inch, and signal 126 represents an unfolded single bill. As shown in Fig. 7, these three signals are sufficiently high enough to surpass the present detection threshold, triggering comparator 92. Signal 128 represents idle noise picked up by the circuitry; it is not strong enough to activate comparator 92.

Due to the fact that commercially available pre-aligned detector modules do not necessarily exhibit precisely identical characteristics, the operating curves of different detectors may vary. Fig. 8 is a graph showing curves 140 and 142 representing the output voltages of two detectors with respect to the displacement of the graded density film strip which is used in the currency dispensor monitor. The graphs show that as the distance from the dark-to-light transition area of the film strip increases the output voltages of the detectors increase in a linear fashion.

To achieve uniform results from the monitor using commercially available detectors, it is necessary to normalize the output of the detector at a known point in the linear region of its operating curve. Referring to Fig. 8, it can be seen that if the film strip is "centered" at a displacement of 0.317 centimeters, a linear operating range of 0.254 centimeters can be easily obtained from curves 140 and 142. Using the displacement of 0.317 centimeters, each detector can be normalized in the circuitry of Fig. 3 by adjusting potentiometer 52 until the current through photodiode 46 of the detector module 36 reaches a prescribed level while the output voltage of the phototransistor 40 is held at a fixed level. The current level was analytically and experimentally determined to be 590 microamps,

using a 4 volt output across phototransistor 40. The normalized operating curves 140a and 142a of the detectors used in Fig. 8 are shown in Fig 9. The graph of Fig. 9 plots the normalized detector output against the "centered" or normalized position of the film strip. Curves 140a and 142a show that, over a 0.254 centimeter range (± 0.127 centimeters from the normalized position), the output voltages of two commercial detectors can be normalized to obtain a uniform response.

Typical values of the components of the circuit of Fig. 3 may be as follows:

Resistors	Value
82,88,100,106	.1K ohms
72,47,94,58	6.8K ohms
78	390 ohms
49	33K ohms
64	750 ohms
62	7.5K ohms
54	680 ohms
56	820 ohms

Capacitors	Value
43	.01 microfarads
44,74	4.7 microfarads
50	15 microfarads
96	1 microfarad
50	100 picofarads

Potentiometers	Value
52, 84, 102	500 ohms

Diodes	Value
80	1N748A
66	1N906

CLAIMS:

1. An apparatus for detecting the passage of multiple documents (10) in a transport system, including gauging means (16, 20, 22) through which documents (10) are arranged to pass, said gauging means (16, 20, 22) being displaceable by an extent dependent on the thickness of one document or multiple documents passing therethrough, characterized by detecting means (34, 36) which is coupled to said gauging means (16, 20, 22) and which is arranged to produce an output (45) which progressively varies in response to a displacement of said gauging means (16, 20, 22), and circuit means (70, 92), responsive to said detecting means (34, 36), for producing an indication of whether multiple documents (10) have simultaneously passed through said gauging means (16, 20, 22).

2. An apparatus according to claim 1, characterized in that said detecting means (34, 36) includes control means (34) which is attached to said gauging means (16, 20, 22) and which is arranged to vary the output (45) of said detecting means (34, 36) in dependence on the magnitude of displacement of said gauging means (16, 20, 22).

3. An apparatus according to claim 2, characterized in that said gauging means (16, 20, 22) includes a pair of cooperating rollers, between which the documents (10) are arranged to pass, comprising a first fixed roller (20) and a second roller (22) movable with respect to said first roller (20), said control means (34) being mechanically coupled to an arm (16) carrying, and movable with, said second roller (22).

4. An apparatus according to claim 2, characterized in that said control means (34) is a member of

4. (concluded)
varying translucency and is arranged for movement between a light source (46) and a light sensing means (40) included in said detecting means, in dependence on displacement of said gauging means (16, 20, 22), the arrangement being such that said light sensing means (40) produces an output (45) the magnitude of which varies in response to movement of said control means (34).

5. An apparatus according to claim 4, characterized in that said control means (34) is a translucent member of graded optical density.

6. An apparatus according to claim 5, characterized in that the optical density of said control means (34) is graded linearly.

7. An apparatus according to claim 4, characterized in that said light source (46) is a photodiode, said light sensing means (40) is a phototransistor and said control means (34) is a strip of photographic film having a graded optical density.

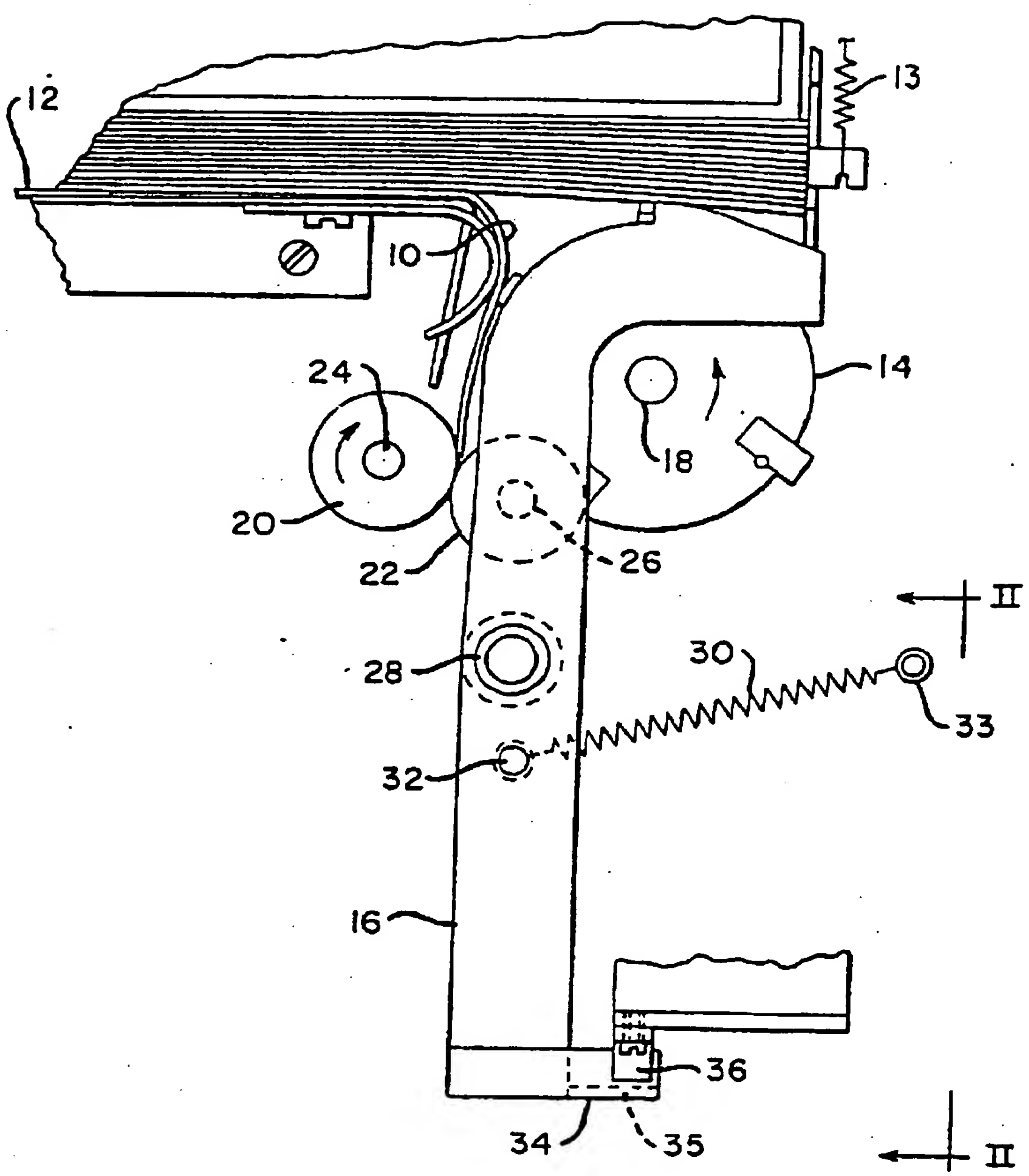
8. An apparatus according to claim 1, characterized in that said circuit means (70, 92) is responsive to said output (45) from said detecting means (34, 36) for generating a plurality of signals (86, 104) indicative of certain conditions as the documents (10) pass through said gauging means (16, 20, 22).

9. An apparatus according to claim 8, characterized in that said circuit means (70, 92) generates a first signal (86) corresponding to a condition wherein multiple documents (10) simultaneously pass through said gauging means (16, 20, 22), and a second signal (106) corresponding to a condition wherein at least a single

9. (concluded)
document (10) passes through said gauging means (16, 20, 22).

10. A currency dispenser incorporating an apparatus according to any one of the preceding claims, characterized in that said circuit means (70, 92) is arranged to give an indication of whether multiple currency bills have simultaneously passed through said gauging means (16, 20, 22).

FIG. 1



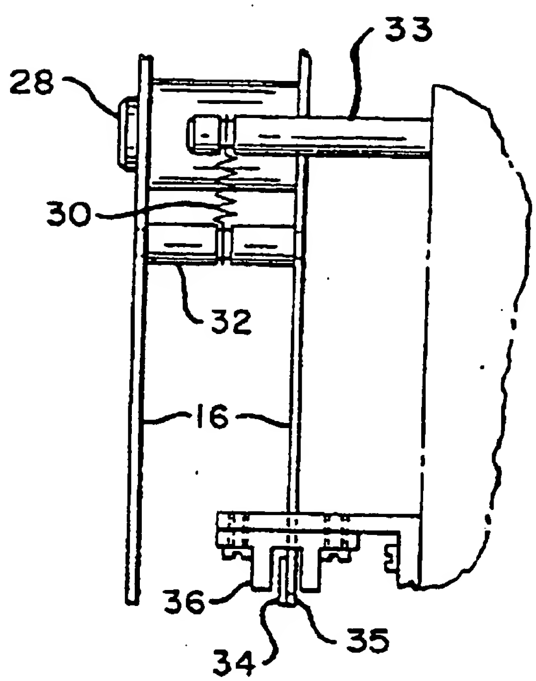


FIG. 2

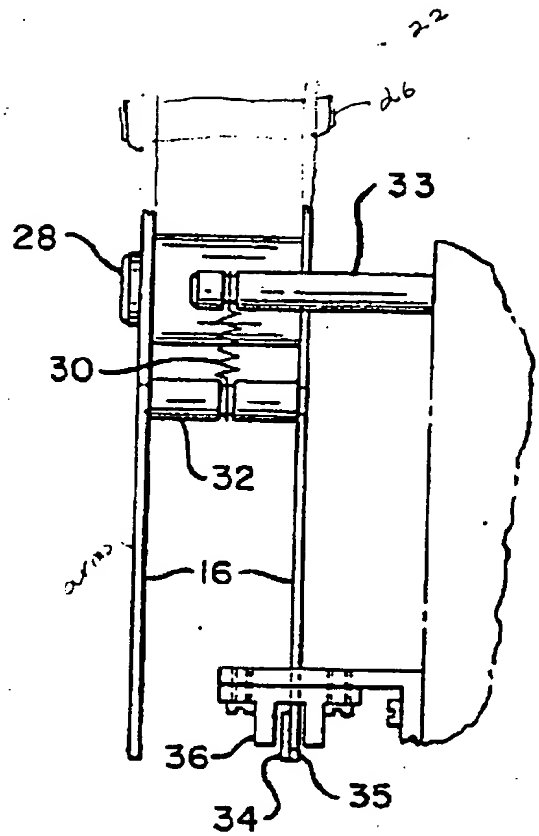
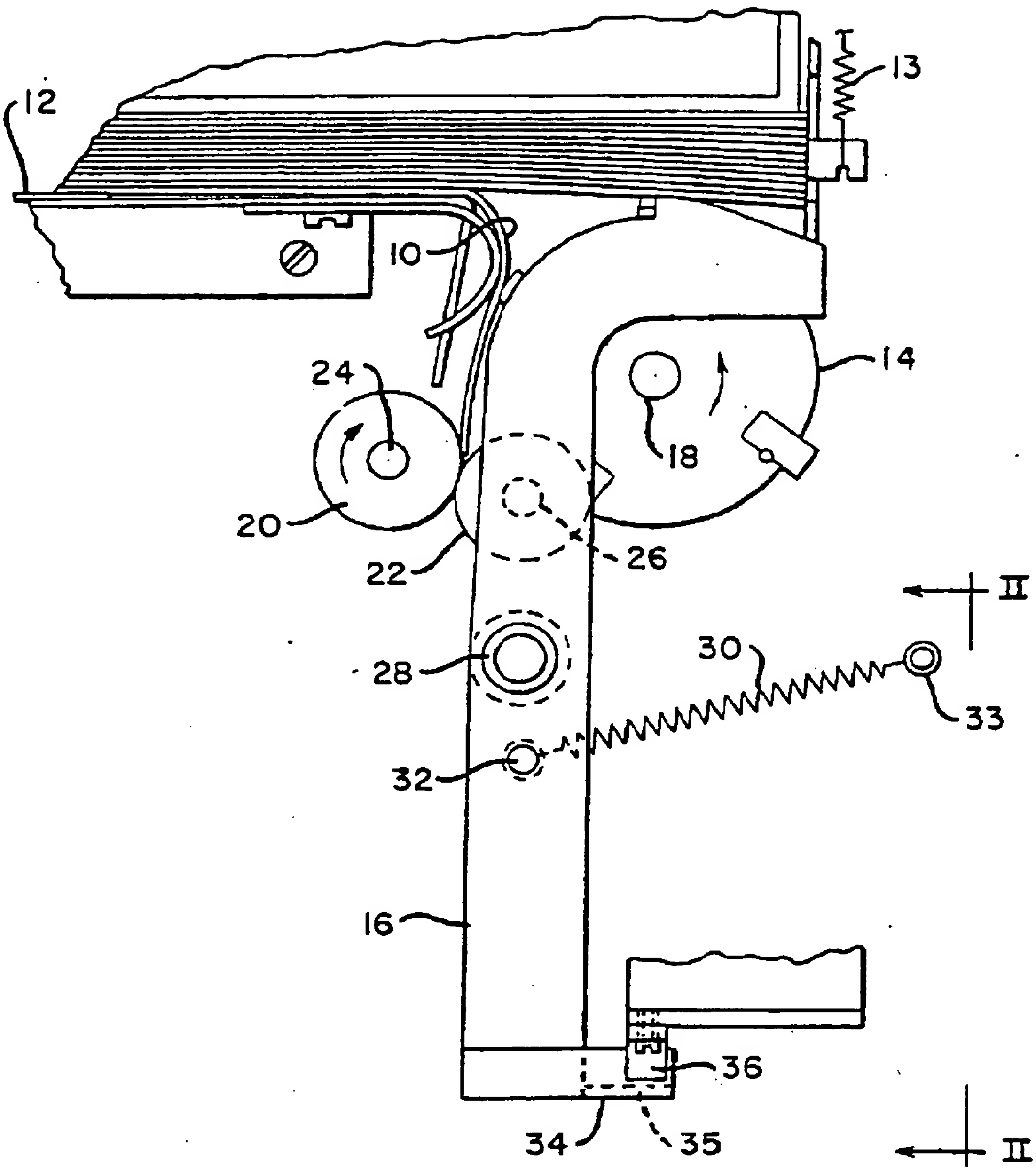
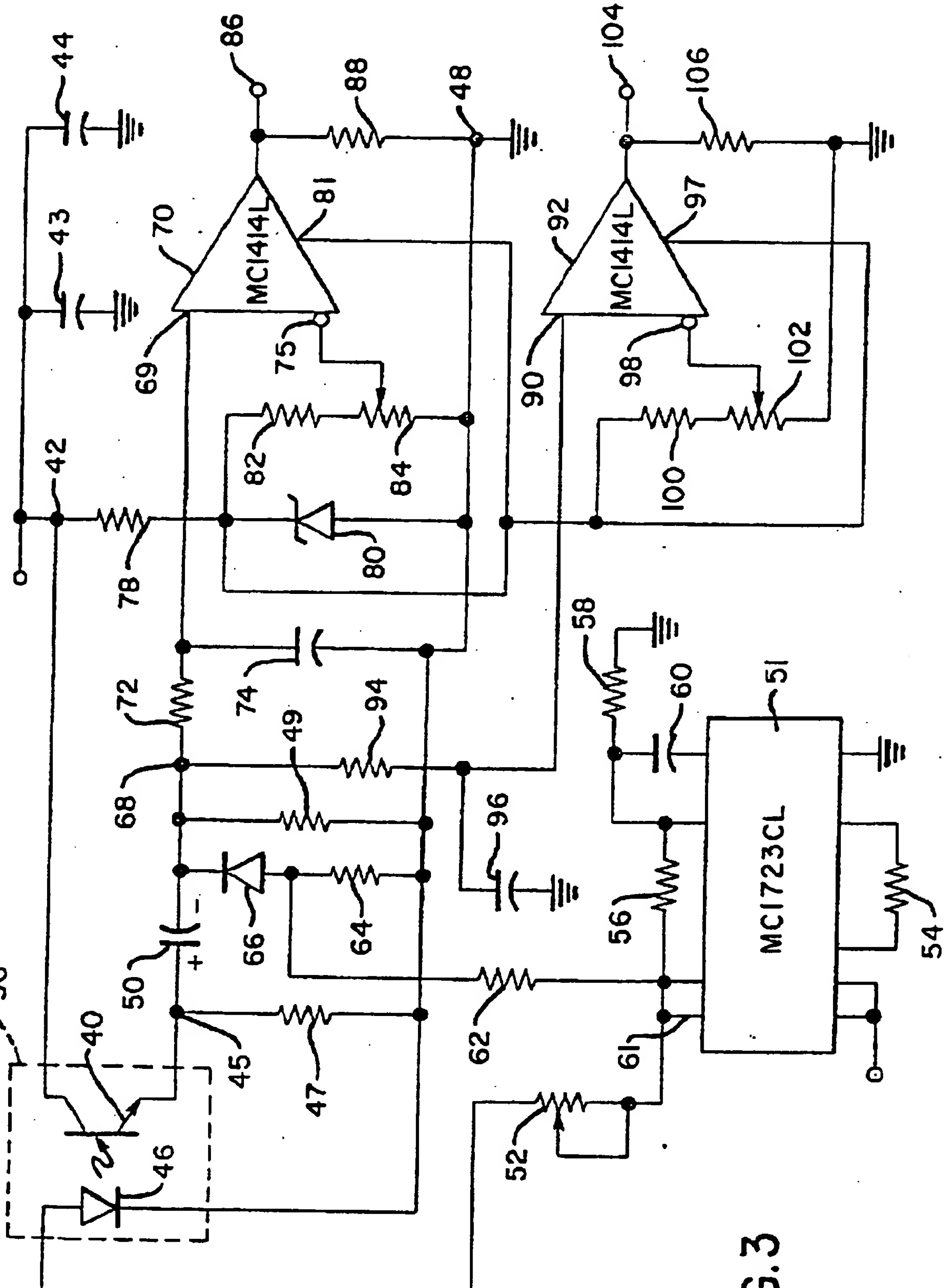


FIG. 2

FIG. 1



3/7



MC1414L
MC1414L
MC1723CL
36
40
42
43
44
45
46
47
48
49
50
51
52
54
56
58
60
61
62
64
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68
69
70
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92
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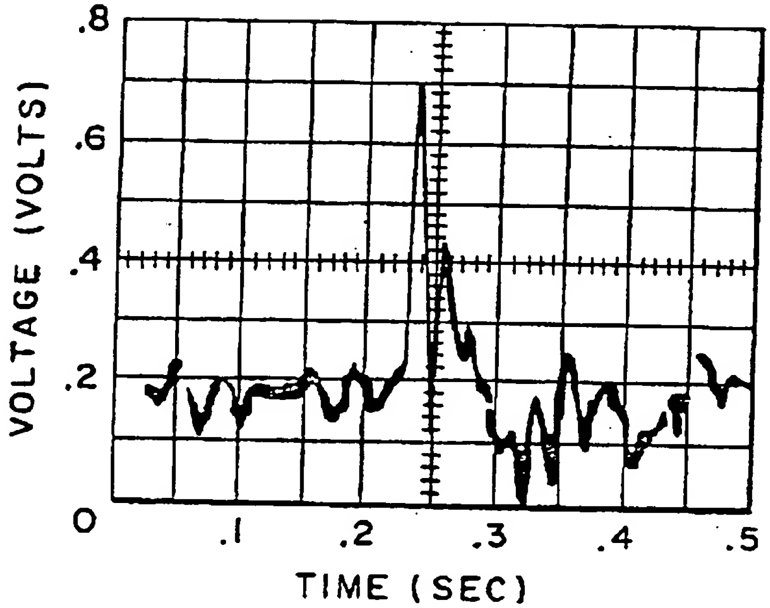
96
97
98
100
102
104
106

FIG.3



.8
.6
.4
.2
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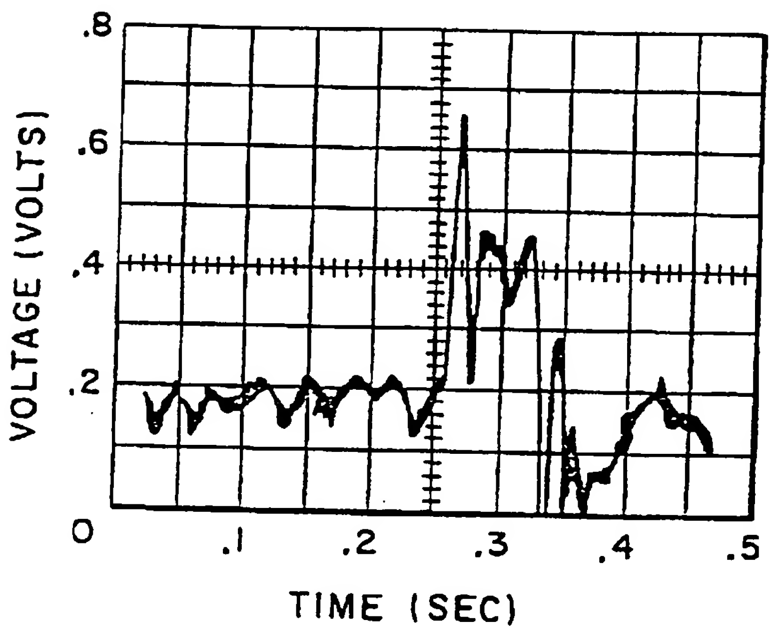
VOLTAGE (VOLTS)
.1
.2
.3
.4
.5
TIME (SEC)

FIG. 4



.8
.6
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VOLTAGE (VOLTS)
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.3
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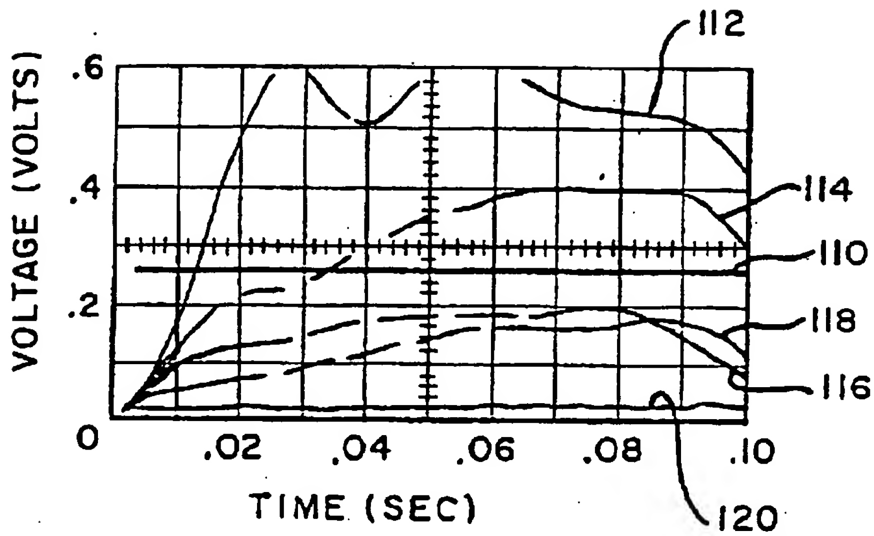
.5
TIME (SEC)

FIG. 5

FIG. 6


112
114
110
118
116
120
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.6
.4
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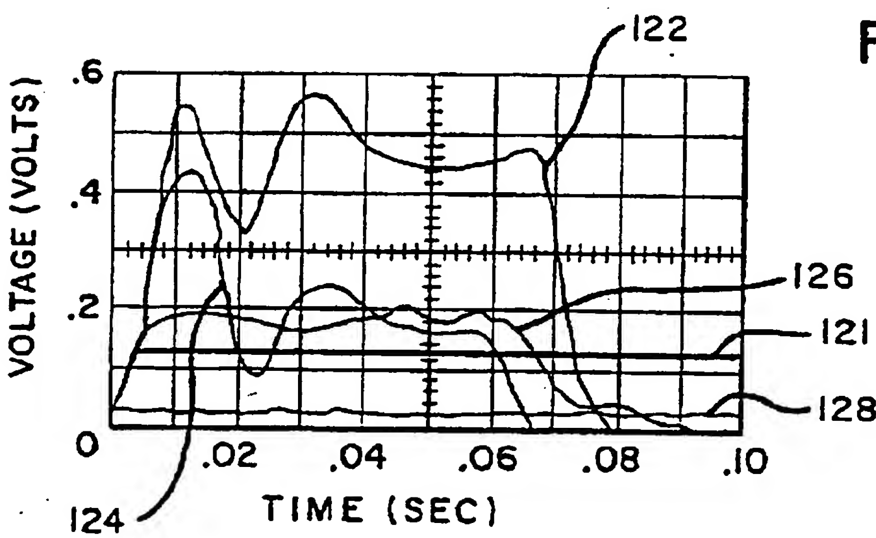
0
.02
.04
.06
.08
.10
TIME (SEC)

FIG. 7


122
126
121
128
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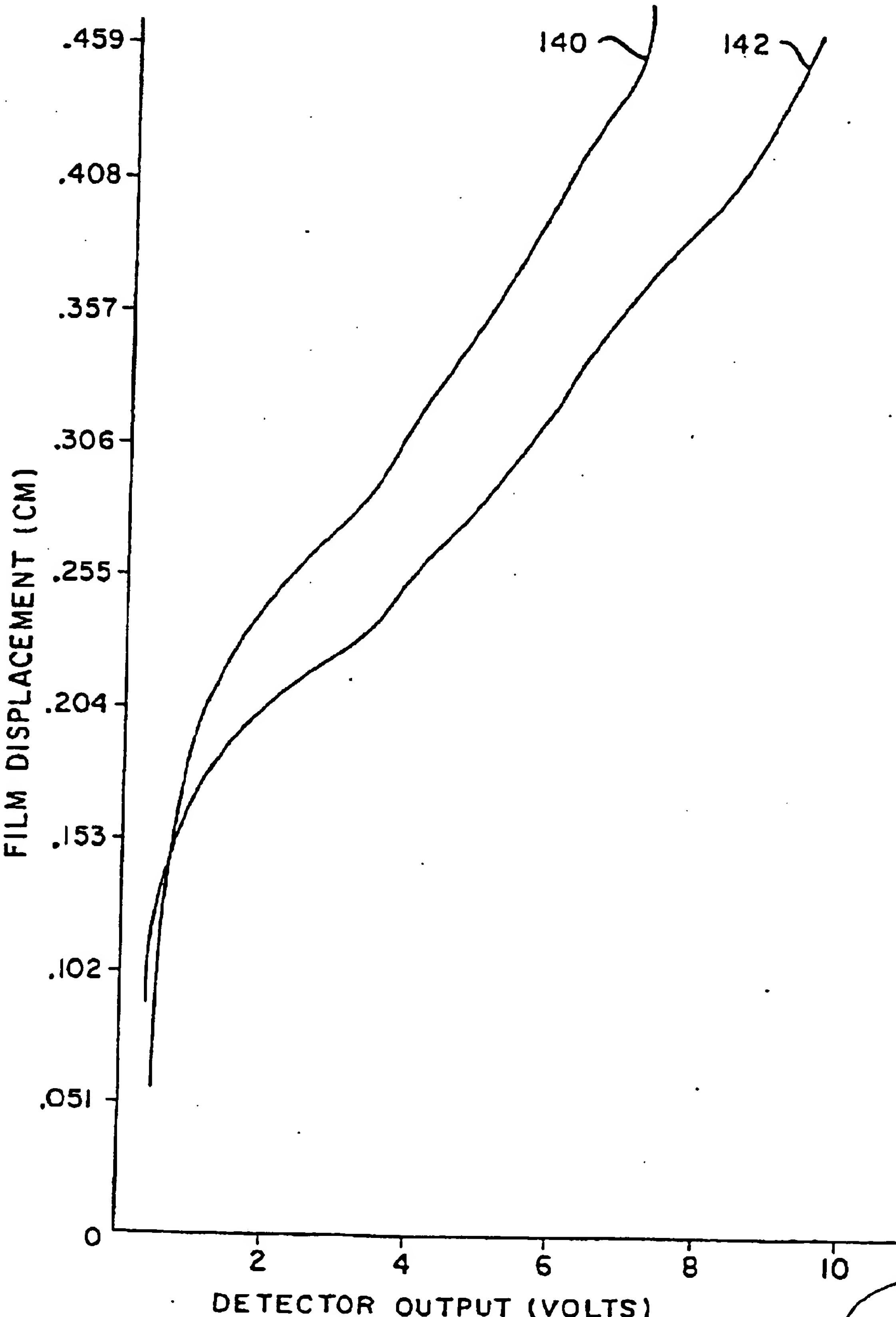
.2
0
.02
.04
.06
.08
.10
TIME (SEC)

FIG. 8


.459
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.204
.153
.102
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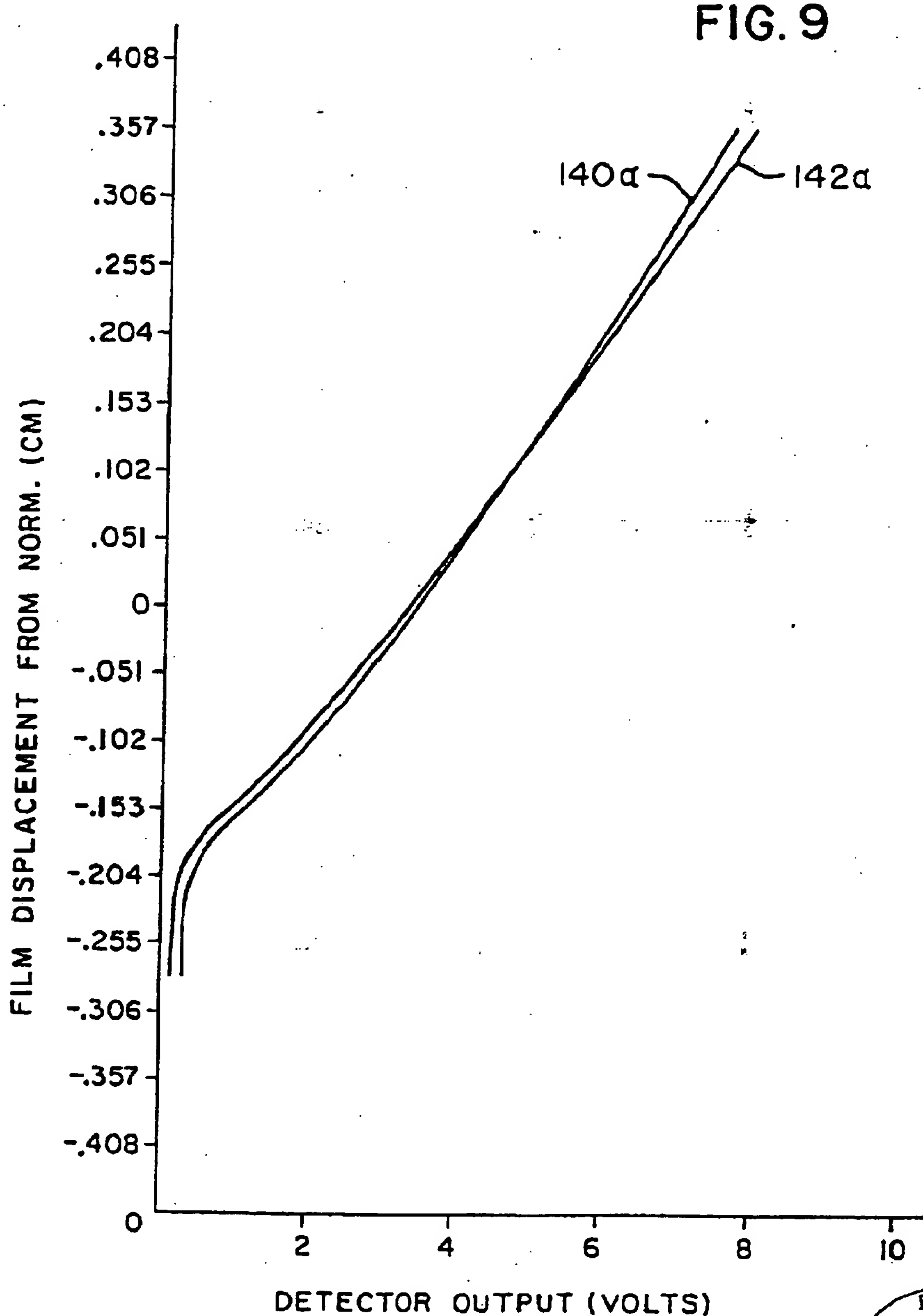
FILM DISPLACEMENT (CM)
140
142
2
4
6
8
10
DETECTOR OUTPUT (VOLTS)

FIG. 9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-.357
-.408
0
2
4
6
8
10
140a
142a
FILM DISPLACEMENT FROM NORM. (CM)
DETECTOR OUTPUT (VOLTS)

INTERNATIONAL SEARCH REPORT

International Application No PCT/US80/01720

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[3] B65H 7/14,7/12

U.S. Cl. 271/263; 250/231R; 340/675; 356/381

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	271/262,263 356/381 340/674,675 250/231R, 559,571 209/603

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	US, A, 2,445,046 Published 13 July 1948, Tinkham	4-7
A	US, A, 3,337,739 Published 22 August 1967, Sendro	4-7
A	US, A, 3,770,965 Published 6 November 1973, Edwards	4-7
X	US, A, 3,918,704 Published 11 November 1975, Sugiyama	1-2,8-9
A	US, A, 4,160,546 Published 10 July 1979, McMillan	7
A	US, A, 4,168,058 Published 18 September 1979, Granzow	10
A	IBM Technical Disclosure Bulletin, volume 7, number 8, issued January 1965 (Armonk, New York), L.L. Amundson 'Double Document Detector', see page 715.	3

* Special categories of cited documents: [15]

"A" document defining the general state of the art

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"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention

"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
10 April 1981	06 MAY 1981
International Searching Authority [1]	**Signature of Authorized Officer** [20]
ISA/US	Bruce H. Stoner Jr. B. Stoner

Form PCT/ISA/210 (second sheet) (October 1977)